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# Disarticulation of the knee: Analysis of an extended database on survival, wound healing, and ambulation

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## ABSTRACT

**Objective:** This study analyzed survival of the amputee patients, wound healing, and ambulation after knee disarticulation (KD).

**Methods:** Between July 1989 and October 2015, 153 KDs in 138 patients were performed at Nij Smellinghe Hospital, Drachten. Data were retrieved from hospital medical records. Wound healing was analyzed using nonparametric tests. Ambulation was recorded according to the Special Interest Group Amputation Medicine Workgroup Amputation and Prosthetics mobility scale.

**Results:** Survival at 1, 6, and 12 months was 86%, 65%, and 55%, respectively. Wounds healed in 91% of patients. Wounds healed primarily in 57% of residual limbs, and healing was delayed in 33%. A transfemoral amputation (TFA) was performed in 10%. Patients with sagittal flaps had significantly poorer primary wound healing and delayed wound healing more often than patients with a dorsal-myocutaneous (dorsomyocutaneous) flap ($P < .027$). In total, 62% of patients were provided with a prosthesis. Preoperatively, 71% of the patients had intention to ambulate with prosthesis, of which 91% received prosthesis. Of these, 35% walked without the help of others. KD amputee patients who underwent a reamputation at the transfemoral level were significantly less ambulant than amputee patients who did not ($P < .021$).

**Conclusions:** If feasible, the dorsomyocutaneous flap technique seems to be the treatment of choice in KD. Because the wound complication rate of the group with a dorsomyocutaneous flap and the percentage of amputee patients who received prosthesis after KD fell within the same range as TFA amputee patients, KD may be an appropriate alternative when surgeons consider a TFA. (J Vasc Surg 2017;66:866-74.)

Each year, ~3300 major lower limb amputations are performed in The Netherlands.[1] Whenever a transtibial amputation (TTA) is not feasible, a more proximal knee disarticulation (KD) or transfemoral (TF) amputation (TFA) should be considered.[2] In contrast to TFA, KD offers several advantages. Surgically, KD is simple, quick to perform, and less traumatic because no bone has to be dissected.[3] Clinically, the most important advantages of a KD is less energy consumption during walking and the potential for direct load transfer to the residual limb compared with TFA.[4,5] Surgeons often avoid KDs because of assumed wound healing complications and poor prosthetic fitting skills.[6,7] These arguments might be no longer relevant because surgical techniques and prosthesis technology have improved considerably.[4]

In an effort to minimize the disadvantages of KD, several modifications with a variety of surgical flap designs have been devised.[8] Instead of a long anterior flap used previously, sagittal flaps have been promoted (Fig 1).[7] The benefit of this technique is that shorter tissue flaps are necessary to close the wound, resulting in improved wound healing.[6] However, these flaps are rather thin, consist of only skin and subcutaneous tissue, and have been dissected with loss of blood vessels penetrating this fascia.[9]

A long dorsal-myocutaneous (dorsomyocutaneous) flap was introduced (Fig 2) in 1985.[9,10] This flap includes gastrocnemius muscle bellies and posterior calf skin with preservation of perforating vessels. It provides excellent padding and blood supply, seems to prevent flap necrosis, and is comfortable for prosthetic rehabilitation because of the thick and mobile distal flap.[7,9]

Whether these developments in surgical flap designs have resulted in improved survival, wound healing, and ambulation in KD amputee patients is unknown. When combined with modern polycentric prosthetic joints, KD can offer improved walking stability in the geriatric population, enabling the performance of activities of daily living and thereby independence and a better quality of life.[11-13]

The aim of this study was to analyze survival of the amputee patient, wound healing, and ambulation after KD with preservation of the femoral condyles in patients

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with peripheral arterial disease (PAD). Outcomes of this study may provide new insights in the determination of indication criteria for KD.

## METHODS

This study was a retrospective cohort study at Nij Smellinghe Hospital, Drachten, The Netherlands, and was approved by the Medical Ethics Committee (ref: NH/SP/15-0827). Between July 1985 and October 2015, 385 major lower limb amputations in 329 patients were performed at Nij Smellinghe Hospital. The study included all patients who underwent a KD, leaving 138 patients with 153 KDs for analysis. No patient informed consent was obtained. There were no exclusion criteria. One surgeon (H.V.) performed 94% of these amputations. Outcome variables were survival of the amputee patient, wound healing, and ambulation after KD in patients predominantly with PAD.

Date of the KD procedure was recorded from the surgical procedure report. Date of death was verified using the hospital's computerized medical record. Data regarding patient characteristics, reason for KD, previous ipsilateral revascularization procedures, other (bilateral) amputation procedures, concomitant diseases, smoking, and wound healing were retrieved from medical records. Most of the data were gathered from the software program used at the hospital. Other data, generally before 2000, were retrieved from paper medical records from the archive.

Patient characteristics included gender and date of birth. The reason for KD was categorized into acute or chronic vascular disease and infection. Previous ipsilateral revascularization procedures, a previous ipsilateral TTA, a reamputation at the TF level, and other bilateral amputation procedures starting from TTA were registered, including date of the procedure.

Wound healing was categorized into primary wound healing, delayed wound healing, or complicated wound healing resulting in TFA. Primary wound healing included wounds of which the stitches could be removed after 3 weeks without problems. Delayed wound healing included wound infection, proven by positive wound cultures and use of antibiotics. Complicated wound healing included an open wound 3 weeks after amputation, making other measures such as vacuum-assisted closure and reamputation at TF level necessary.

The following comorbidities were included for analysis: PAD, diabetes mellitus, cardiovascular disease, renal failure, cerebrovascular disease, chronic obstructive pulmonary disease (Global Initiative for Chronic Obstructive Lung Disease stage III or IV), and rheumatism. Whether a patient was suffering from comorbidity was retrieved from medical records. In case of unclear descriptions, the attending surgeon (H.V.) decided the type of comorbidity based on description of signs and symptoms and diagnostic outcomes. Smoking was categorized as smoker, nonsmoker, or former smoker.

### ARTICLE HIGHLIGHTS

- **Type of Research:** Single-center retrospective cohort study
- **Take Home Message:** In 115 early survivors of knee disarticulation (KD), primary wound healing with dorsomyocutaneous flaps was 85%, significantly higher than in those with sagittal flaps (53%). Sixty-two percent received prosthesis, and 35% walked independently after KD.
- **Recommendation:** This study suggests KD with dorsomyocutaneous flap closure as a good alternative to transfemoral amputation for selected patients.

Data concerning prosthetic fitting and ambulation were retrieved from medical records of the hospital and the rehabilitation physician. Three variables were recorded: whether the patient received a functional prosthesis, whether there was (preoperative) intention for prosthesis use, and the Special Interest Group Amputation Medicine Workgroup Amputation and Prosthetics (SIGAM-WAP) mobility score, which assesses mobility with leg prosthesis.[14] The SIGAM-WAP score was used to categorize patients into five scales: Scale A includes patients who did not receive prosthesis, do not use their prosthesis, or use their prosthesis only ornamentally. Scale B includes patients who received a prosthesis but only use the prosthesis for transfer or to assist in care or walk only with the help of others or during exercise therapy. Scale C includes patients who only walk on flat surface or $<$50 meters, with or without the help of a walking aid. Scale D includes patients who walk $>$50 meters, only on flat surface and in good weather, with or without walking aids. Scale E includes patients who walk $>$50 meters, without walking aid or just to be sure, on uneven or slippery terrain.

**Statistical analysis.** The data were analyzed using SPSS 23 software (IBM Corp, Armonk, NY). $P \leq .05$ was considered as statistically significant.

Patient survival at 1, 6, and 12 months was analyzed in a Kaplan-Meier curve. If the patient was still alive, the date of the first analysis of this study (January 20, 2016) was used to analyze the survival. In bilateral KD amputee patients, the first amputation was included for analysis. If the date of the KD amputations was the same, the first amputation in the database was included. Difference in survival between unilateral and bilateral KD amputee patients, patients whose amputation occurred between July 1989 to March 2006, and April 2006 to October 2015, and patients with a previous ipsilateral TTA, a reamputation at the TF level, or no other ipsilateral amputation were also analyzed using a log-rank test. Data of

**Fig 1.** Sagittal flaps: Equal and short flaps.

patients treated from July 1989 until March 2006 in Nij Smellinghe Hospital have been published previously.[2]

The overall wound healing analysis was performed per residual limb. This analysis excluded data of 27 patients who died ≤1 month or before leaving the hospital. Differences in wound healing were analyzed using the Mann-Whitney *U* test and the Kruskal-Wallis test. These analyses were performed per patient, instead of per residual limb, to avoid concomitant diseases being included twice.

In the prosthesis fitting and SIGAM-WAP analysis, the maximum level achieved after KD was registered for both unilateral and bilateral patients. Ambulation was categorized into the highest SIGAM-WAP level recorded. The following patients were excluded from analyses of discharge destination and ambulation, including prosthesis fitting and SIGAM-WAP scores: patients who died during the hospitalization or ≤1 month after amputation (n = 23), who underwent a reamputation at the TF level (n = 12), and of whom the only known data were whether

**Fig 2.** The dorsomyocutaneous flap includes gastrocnemius muscle bellies and posterior calf skin as a combined flap, without destruction of the perforating vessels.

these patients preoperatively had the intention to walk with a prosthesis (n = 7). Data of 10 patients were incomplete. The difference in ambulation between patients who did and did not undergo a bilateral amputation and between patients who did and did not undergo a reamputation at the TF level were analyzed using the Mann-Whitney *U* test.

## RESULTS

In total, 145 TTA, 153 KD, and 87 TFA were performed. Of the KD amputee patients, 57 were women (41%). The mean age at time of amputation was 74.2 ± 12.7 years. The median age of women (79.0 years; interquartile range [IQR], 69.5-84.0 years) was older than the median age of men (75.0 years; IQR, 68.0-80.0 years; $P = .048$).

**Table I.** Characteristics of 138 patients undergoing 153 knee disarticulations (*KDs*)

| Variables | Percentage (n/N)[a,b] |
|---|---|
| Age, years | |
| ≤74.2 years | 41.3 (57/138) |
| >74.2 years | 58.7 (81/138) |
| Gender | |
| Male | 58.7 (81/138) |
| Female | 41.3 (57/138) |
| Concomitant diseases | |
| PAD | 97.8 (135/138) |
| DM | 63.0 (87/138) |
| Cardiovascular disease | 62.2 (79/127) |
| Renal failure | 46.9 (61/130) |
| Cerebrovascular disease | 36.2 (50/138) |
| COPD | 11.7 (15/128) |
| Rheumatism | 4.7 (6/127) |
| Concomitant diseases, No. | |
| ≤3 comorbidities | 57.2 (79/138) |
| ≥4 comorbidities | 42.8 (59/138) |
| Smoking | |
| Smoker | 50.5 (49/97) |
| Nonsmoker | 34.0 (33/97) |
| Former smoker | 15.5 (15/97) |
| Previous ipsilateral procedures | |
| Revascularization | 32.6 (45/138) |
| Transtibial amputation | 8.7 (12/138) |
| Reason for amputation | |
| Acute or chronic vascular disease | 96.4 (133/138) |
| Infection | 3.6 (5/138) |
| Amputated side | |
| Right | 41.3 (57/138) |
| Left | 47.8 (66/138) |
| Bilateral | 10.9 (15/138) |
| Wound healing | |
| Primary | 57.1 (72/126) |
| Delayed | 33.3 (42/126) |
| No wound healing resulting in TFA | 9.5 (12/126) |
| Postoperative stump dressing | |
| Elastic bandage | 63.4 (97/153) |
| Plaster of Paris | 36.6 (56/153) |
| Discharge destination | |
| Nursing facility | 60.0 (81/135) |
| Rehabilitation center | 16.3 (22/135) |
| Rehabilitation day care | 5.9 (8/135) |
| Home | 4.4 (6/135) |
| Died in hospital | 13.3 (18/135) |
| Discharged KD amputee patients | |
| Provided with prosthesis | 61.6 (53/86) |
| Not provided with prosthesis | 38.4 (33/86) |
| SIGAM-WAP mobility scale | |
| Scale A | 39.5 (34/86) |
| Scale B | 25.6 (22/86) |
| Scale C | 24.4 (21/86) |
| Scale D | 5.8 (5/86) |
| Scale E | 4.9 (4/86) |

*COPD,* Chronic obstructive pulmonary disease; *DM,* diabetes mellitus; *PAD,* peripheral arterial disease; *SIGAM-WAP,* Special Interest Group Amputation Medicine Workgroup Amputation and Prosthetics; *TFA,* transfemoral amputation.
[a]n/N = observed frequency/number of available data.
[b]The percentages >100% because of rounding.

Acute or chronic vascular disease was the reason for amputation in 96% of patients (Table I), and 95% of these patients had gangrene. Nearly all patients had PAD (98%). The median follow-up was 1.0 year (IQR, 0.2-3.8 years) and the median hospitalization time was 25.0 days (IQR, 12.0-51.5 days).

Survival at 1, 6, and 12 months was 86%, 65%, and 55%, respectively (Fig 3). After patients who died early were excluded, a data set of 115 patients with 126 residual limbs was available for analysis. Of these residual limbs, 72 wounds (57%) healed primarily and 42 wounds (33%) had delayed healing (Table I). Complete wound healing occurred in 114 wounds (90%). Wound healing in 12 residual limbs (10%) was complicated and TFA was performed. The median interval between KD and reamputation at the TF level was 1.1 months (IQR, 0.7-2.7 months). A prothesis was received by 55% of the patients with delayed wound healing and by 66% with primary wound healing.

Only the type of incision was significantly associated with wound healing problems (Table II). Primary wound healing was significantly poorer in patients with sagittal flaps (53%) than in patients with a dorsomyocutaneous flap (85%). There was no significant difference in survival between patients with a unilateral or bilateral KD ($P = .391$), between patients whose amputation occurred between July 1989 to March 2006 and April 2006 to October 2015 ($P = .410$), or between patients with a previous ipsilateral TTA, a reamputation at the TF level, or in whom no other ipsilateral amputation was found ($P = .680$).

After the exclusion of patients who died during hospitalization or ≤1 month after amputation, who underwent a reamputation at TF level, or those with missing data on preoperative intention to walk with prosthesis, a data set of 96 patients was available for analysis of discharge destination, prosthesis fitting, and SIGAM-WAP (Table I). Of these 96 patients, 86 had complete data sets and 53 (62%) were provided with a prosthesis. Preoperatively, 71% (58 of 82) of the patients had intention to ambulate

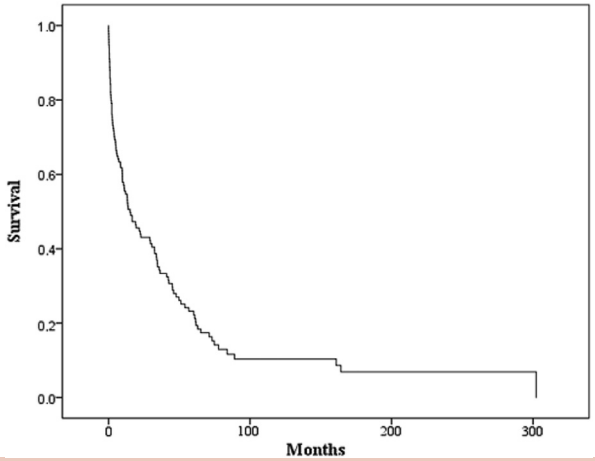


**Fig 3.** Overall survival after knee disarticulation (KD) in months based on data of 134 patients. Data for four patients were incomplete.

with a prosthesis, of which 91% (53 of 58) received a prosthesis. Of patients with sagittal flaps, 63% received prosthesis, while 50% of the patients with a dorsomyocutaneous flap received prosthesis. Of the 86 patients, 35% (n = 30) were classified into scale C or higher of the SIGAM-WAP scale. The amputations were bilateral in 33 patients (24%): 9 patients at the TTA level, 15 at the KD level, and 9 at the TF level. Patients who underwent a reamputation at the TF level were classified significantly lower on SIGAM-WAP scale than those without reamputation (Table III).

## DISCUSSION

A review involving KD found primary healing ranged between 60% and 100%, delayed healing between 0% and 26%, and reamputation between 0% and 21%.[7] In our study, primary and delayed wound healing of patients with a dorsomyocutaneous flap was similar, but wound healing in patients who received sagittal flaps was less favorable.

In the dorsomyocutaneous flap technique, a transverse incision is made cranially to the tuberositas tibiae, basically imitating an extremely short TTA incision. Length of the patellar ligament was preserved by cutting this at its distal end. By going straight through the cruciate and collateral ligaments, the knee joint opens up and the complete soft tissue covering at the back of the tibia and fibula is removed, preserving the blood supply. The length of the flap is determined by how thick the gastrocnemius muscle bellies are. In most cases, removing the soleus muscle is enough to allow for closure without tension.

Whether the differences in wound healing in our study can be solely attributed to the type of incision is unclear. Sagittal flaps were first used in 1989, initially in emergency cases for life saving, speed of surgery, and minimal blood loss. The appearance of pressure ulcers at the femur condyles in high-risk patients made it necessary to look for a more bulky cover, and the dorsomyocutaneous technique was introduced in 2008. The skills of the surgeon may have developed as he gained experience over time. Prosthetics did not result in more pressure sores and wound complications for the two flaps because a prosthesis was not measured until complete wound healing had occurred.

The ambulation rate for KD amputee patients in a systematic review ranged from 13% to 75%.[7] The prosthetic ambulation rates in two retrospective studies evaluating sagittal flaps were 31% and 53%, and the rate of one retrospective study evaluating a dorsomyocutaneous flap was 75%. Our rate of 62% fell within the same range compared with these percentages. However, 63% of the patients in our study with sagittal flaps received prostheses, whereas 50% of the patients with a dorsomyocutaneous flap received prostheses. Prosthetic rehabilitation in patients with a dorsomyocutaneous flap was expected to be higher because of the thick and mobile distal flap.[9] This result might be related to the small group of patients with a dorsomyocutaneous flap.

In the literature, 30-day survival of TFA patients ranged between 73% and 90% and 1-year survival between 42% and 69%.[11,15-17] Our survival data fell within the same range. A retrospective study found a higher survival rate for TTA than for TFA.[18] Patients who underwent TTA may have had a better health at time of the amputation than patients who underwent KD or TFA. When TTA is no longer feasible and the choice has to be made between KD or TFA, the patient's physical condition might be already worse, resulting in similar survival rates for KD and TFA.

Patients who died ≤1 month or before leaving the hospital were excluded from wound healing analysis because the patient's condition could have affected wound healing too much and the period of time to death was too short to assess actual wound healing. In the literature, the wound complication rate after TFA ranged between 7% and 29%, and the reoperation rate (including reamputation) after TFA ranged between 0% and 12%.[16,17,19,20] In our study, delayed wound healing appeared more often after KD than after TFA, as reported in literature. This difference may be attributed to the numerous sagittal flaps in our study. The complication rate of the group with dorsomyocutaneous flaps fell within the same range as the complication rate after TFA. The reamputation rate of all KD amputees in this study also fell within the same range as the reoperation rate after TFA. Because use of a dorsomyocutaneous flap indicated positive wound healing outcomes, further research concerning KDs with a dorsomyocutaneous flap is recommended. KD is not advisable in patients with extreme cachexia or purulent septic arthritis and in case of poor skin quality of <7 cm below the knee joint.

**Table II.** Analysis of differences in wound healing between different groups[a]

| Variables | Wound healing | | | No.[b] | *U* value | *P* value |
|---|---|---|---|---|---|---|
| | Primary, % | Delayed, % | Reamputation TFA, % | | | |
| Unilateral | 58.4 | 30.7 | 10.9 | 101 | 620.00 | .400 |
| Bilateral | 42.9 | 50.0 | 7.1 | 14 | | |
| DM | | | | | | |
| Yes | 50.0 | 40.5 | 9.5 | 42 | 1401.50 | .388 |
| No | 60.3 | 28.8 | 11.0 | 73 | | |
| Cardiovascular disease | | | | | | |
| Yes | 56.4 | 33.3 | 10.3 | 39 | 1269.50 | .782 |
| No | 58.2 | 34.3 | 7.5 | 67 | | |
| Renal failure | | | | | | |
| Yes | 59.7 | 35.5 | 4.8 | 62 | 1292.50 | .460 |
| No | 55.6 | 31.1 | 13.3 | 45 | | |
| Cerebrovascular disease | | | | | | |
| Yes | 55.3 | 38.2 | 6.6 | 76 | 1458.00 | .873 |
| No | 59.0 | 23.1 | 17.9 | 39 | | |
| COPD | | | | | | |
| Yes | 59.4 | 32.3 | 8.3 | 96 | 459.00 | .419 |
| No | 45.5 | 45.5 | 9.1 | 11 | | |
| Rheumatism | | | | | | |
| Yes | 58.8 | 32.4 | 8.8 | 102 | 148.50 | .294 |
| No | 25.0 | 75.0 | 0.0 | 4 | | |
| Concomitant diseases | | | | | | |
| ≤3 | 55.7 | 34.3 | 10.0 | 70 | 1553.50 | .889 |
| ≥4 | 57.8 | 31.1 | 11.1 | 45 | | |
| Age, years | | | | | | |
| ≤74.2 | 53.2 | 34.0 | 12.8 | 47 | 1490.00 | .487 |
| >74.2 | 58.8 | 32.4 | 8.8 | 68 | | |
| Flap | | | | | | |
| Sagittal | 52.9 | 35.3 | 11.8 | 102 | 441.00 | .027 |
| Dorsomyocutaneous | 84.6 | 15.4 | 0.0 | 13 | | |
| Elastic bandage | 58.3 | 29.2 | 12.5 | 72 | 1518.00 | .845 |
| Plaster of Paris | 53.5 | 39.5 | 7.0 | 43 | | |
| Smoker | 48.7 | 38.5 | 12.8 | 39 | 4.190 | .123 |
| Nonsmoker | 57.6 | 33.3 | 9.1 | 33 | | |
| Former smoker | 78.6 | 21.4 | 0.0 | 14 | | |

*COPD*, Chronic obstructive pulmonary disease; *DM*, diabetes mellitus; *TFA*, transfemoral amputation.
[a]All analyses were Mann-Whitney *U* tests, except in the analysis of smoking, for which a Kruskal-Wallis test was performed.
[b]Because of incomplete data, the number of available observations is reported.

However, if a spacer is used in a failed knee joint removal and a second joint replacement or a knee arthrodesis is not feasible, KD is still possible.

A systemic review revealed that there was progressive, significant reduction of ambulation as unilateral amputation height became more proximal from TTA to KD and TFA.[21] For that reason, data were excluded from the ambulation analysis if a patient underwent a reamputation at the TF level. Some patients (n = 34) might have been more ambulant than registered, but follow-up data were not available. These patients were classified into the highest known SIGAM-WAP scale. The likelihood of or the actual receipt of a prosthesis after TFA ranged between 29% and 70%.[16,22] Approximately 20% of the TF amputee patients walked postoperatively, with or without the help of a walking aid.[23,24] In our study, 62% of the KD amputee patients received a prosthesis, and 35% walked without the help of others. KD amputee patients appeared to be more ambulant postoperatively than those who underwent (re-)amputation at the TF level. This result was expected given the theoretical advantages of a KD.

**Table III.** Differences in ambulation between groups

| Variable | SIGAM-WAP mobility scale | | | | | No.[a] | *U* value[b] | *P* value |
|---|---|---|---|---|---|---|---|---|
| | A, % | B, % | C, % | D, % | E, % | | | |
| Bilateral amputation | | | | | | | | |
| Yes | 44.0 | 32.0 | 24.0 | 0.0 | 0.0 | 25 | 633.50 | .198 |
| No | 37.7 | 23.0 | 24.6 | 8.2 | 6.6 | 61 | | |
| Reamputation TFA | | | | | | | | |
| Yes | 88.9 | 0.0 | 0.0 | 11.1 | 0.0 | 9 | 215.50 | .021 |
| No | 39.5 | 25.6 | 24.4 | 5.8 | 4.7 | 86 | | |

*SIGAM-WAP*, Special Interest Group Amputation Medicine Workgroup Amputation and Prosthetics; *TFA*, transfemoral amputation.
[a]Because of incomplete data, the number of available observations is reported.
[b]Results of Mann-Whitney *U* test.

The strength of this study was that almost all of the 153 KDs in 138 patients in the past 27 years were performed by a single vascular surgeon in the northern part of The Netherlands. A comparison of our data with results of TFAs, as described in literature, was hampered because studies presented results in a slightly different way. We did not record quality of life after KD. Whether retaining the knee joint provides a patient a higher quality of life is indistinct. Although most surgeons might assume that outcomes are better after KD than after TFA as a result of greater ambulation with more independence, further research regarding quality of life after lower limb amputation is necessary.

## CONCLUSIONS

If feasible, the dorsomyocutaneous flap technique seems to be the treatment of choice in KD compared with the sagittal flap technique. Because the wound complication rate of the group with a dorsomyocutaneous flap and the percentage of KD amputee patients who received a prosthesis fell within the same range as the TFA amputee patients, KD may be an appropriate alternative when surgeons consider a TFA.

## AUTHOR CONTRIBUTIONS

Conception and design: RN, JG, HV, PD
Analysis and interpretation: RN, JG, PD
Data collection: RN, HV
Writing the article: RN
Critical revision of the article: JG, HV, PD
Final approval of the article: RN, JG, HV, PD
Statistical analysis: RN, PD
Obtained funding: Not applicable
Overall responsibility: JG

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